

## ELECTRODE BINDER SLURRY COMPOSITION FOR LITHIUM ION ELECTRICAL STORAGE DEVICES

### FIELD OF THE INVENTION

[0001] The invention relates to fluoropolymer, such as polyvinylidene fluoride (PVDF), slurry compositions for manufacturing electrodes for use in electrical storage devices, such as batteries.

### BACKGROUND OF THE INVENTION

[0002] There is a trend in the electronics industry to produce smaller devices, powered by smaller and lighter batteries. Batteries with a negative electrode—such as a carbonaceous material, and a positive electrode—such as lithium metal oxides can provide relatively high power and low weight.

[0003] Polyvinylidene fluoride, because of its excellent electrochemical resistance, has been found to be a useful binder for forming electrodes to be used in electrical storage devices. Typically, the polyvinylidene fluoride is dissolved in an organic solvent and the electrode material, that is, in the case of a positive electrode for lithium ion batteries, the electrochemically active lithium compound and a carbonaceous material, the electrical active lithium compound and a carbonaceous material, is combined with the PVDF solution to form a slurry that is applied to a metal foil or mesh to form the electrode.

[0004] The role of the organic solvent is to dissolve PVDF in order to provide good adhesion between the electrode material particles and the metal foil or mesh upon evaporation of the organic solvent. Currently, the organic solvent of choice is N-methyl-2-pyrrolidone (NMP). PVDF binders dissolved in NMP provide superior adhesion and an interconnectivity of all the active ingredients in the electrode composition. The bound ingredients are able to tolerate large volume expansion and contraction during charge and discharge cycles without losing interconnectivity within the electrodes. Interconnectivity of the active ingredients in an electrode is extremely important in battery performance, especially during charging and discharging cycles, as electrons must move across the electrode, and lithium ion mobility requires interconnectivity within the electrode between particles.

[0005] Unfortunately, NMP is a toxic material and presents health and environmental issues. It would be desirable to replace NMP as a solvent for PVDF binders. However, NMP is somewhat unique in its ability to dissolve PVDF that is not nearly as soluble in other organic solvents.

[0006] To effectively employ PVDF compositions in electrode-forming processes in organic solvent other than NMP, the PVDF must be dispersed in the diluent. However, the dispersion must be compatible with current manufacturing practices and provide desired properties of the intermediate and final products. Some common criteria include: a) stability of the fluoropolymer dispersion, having sufficient shelf-life, b) stability of the slurry after admixing the electroconductive powders with the dispersion, c) appropriate viscosity of the slurry to facilitate good application properties, and d) sufficient interconnectivity within the electrode.

[0007] In addition, after the electrodes are assembled in an electrical storage device, the device should be substantially free of moisture and substantially free of hydrophilic groups that may attract moisture.

[0008] It is therefore an objective of the present invention to provide stable PVDF dispersions using alternatives to NMP, for use as binders in preparing electrode-forming compositions having suitable application properties for producing high quality electrodes for batteries and other electrical storage devices having interconnectivity.

### SUMMARY OF THE INVENTION

[0009] The present invention provides a slurry composition comprising (a) an electrochemically active material; (b) a binder comprising (i) a polymer comprising a fluoropolymer dispersed in a liquid medium; and (ii) a polymer comprising an addition polymer comprising constitutional units comprising the residue of a heterocyclic group-containing ethylenically unsaturated monomer.

[0010] The present invention also provides a slurry composition comprising (a) an electrically conductive agent; (b) a binder comprising (i) a polymer comprising a fluoropolymer dispersed in a liquid medium; and (ii) a polymer comprising an addition polymer comprising constitutional units comprising the residue of a heterocyclic group-containing ethylenically unsaturated monomer.

[0011] The present invention further provides an electrode comprising (a) an electrical current collector; and (b) a film formed on the electrical current collector, wherein the film is deposited from a slurry composition comprising an electrochemically active material; a binder comprising: (i) a polymer comprising a fluoropolymer dispersed in a liquid medium; and (ii) a polymer comprising an addition polymer comprising constitutional units comprising the residue of a heterocyclic group-containing ethylenically unsaturated monomer; and an electrically conductive agent.

[0012] The present invention also provides an electrical storage device comprising (a) an electrode comprising an electrical current collector and a film formed on the electrical current collector, wherein the film is deposited from a slurry composition comprising an electrochemically active material; an electrically conductive agent; and a binder comprising: (i) a polymer comprising a fluoropolymer dispersed in a liquid medium; and (ii) a polymer comprising an addition polymer comprising constitutional units comprising the residue of a heterocyclic group-containing ethylenically unsaturated monomer; (b) a counter electrode; and (c) an electrolyte.

### DESCRIPTION OF THE DRAWING

[0013] FIG. 1 is a graph illustrating the first derivative of Log viscosity versus temperature, wherein the peak maximum is used to determine the dissolution temperature of PVDF dispersed in 1,2,3-triacetoxyp propane (triacetin) from the abscissa.

### DETAILED DESCRIPTION

[0014] The present invention is directed to a slurry composition comprising an electrochemically active material; a binder comprising: (i) a polymer comprising a fluoropolymer dispersed in a liquid medium; and (ii) a polymer comprising an addition polymer comprising constitutional units comprising the residue of a heterocyclic group-con-